Short visit grant

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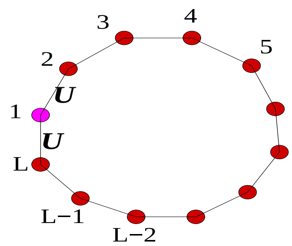
Visit took place in March/April 2011.

Purpose of the visit

The purpose of this research visit was to make progress on our ongoing research on *persistent currents* through an Interacting Resonant Level Model (IRLM) impurity.



Lattice ring version of the IRLM. Site 1 is the impurity site. A nearest neighbor interaction acts across the 1-2 and 2-3 bonds. The hopping amplitudes across these two bonds are different from the rest of the ring.

Non-equilibrium transport through quantum impurities has been the subject of intense theoretical and experimental interest during the past decade. A typical situation is steady-state transport through an impuirty connecting two leads set at different chemical potentials, i.e., subject to a voltage bias. The Interacting Resonant Level Model (IRLM) has become the standard impurity model studied in this context (c.f., Ref. [1–3] and many other recent studies). This is arguably the simplest theoretical impurity model with interactions, and as such, plays an extremely valuable role in extracting the essential features of the physics of transport through an impurity.

There is another natural physical context where a steady current passes through an impurity, namely, the current persisiting through a ring after a magnetic flux through the ring is turned on. When the ring contains an impurity, this becomes a realization of steady current flowing through an impurity. The topic has been studied previously for a number of more complicated impurity models [4, 5]. We believe an IRLM impuiry embedded in a ring carrying a persistent current will provide important insights to the general question of transport through an interacting impurity.

We are studying a lattice version of the IRLM (usually defined in a continuum setting), placed in an otherwise non-interacting tight-binding ring. The magnetic flux is manifested as a complex phase ϕ in the hopping term. The principal object of study is the I-ϕ curve, i.e., current as a function of magnetic flux. The model is schematically explained in the Figure and its caption. The Hamiltonian is

$$H \ = \ -\sum_{i=2}^{L-1}\left[e^{-i\phi/L}c_i^\dagger c_{i+1} + \text{h.c.}\right] \ - \ \left[te^{-i\phi/L}(c_1^\dagger c_2 + c_L^\dagger c_1) \ + \ \text{h.c.}\right] + \text{interaction}$$

where h.c. means hermitian conjugate. The interaction term is particle-hole symmetric: $U\left[\left(n_1-\frac{1}{2}\right)\left(n_2-\frac{1}{2}\right)+\left(n_1-\frac{1}{2}\right)\left(n_L-\frac{1}{2}\right)\right]$. We concentrate on the regime $t << 1$, where the impurity hopping is much smaller than the bandwidth of the tight-binding ring.

Description of the work carried out during the visit + main results obtained

During this visit we extended a scaling analysis of the I-ϕ curves, that we have been developing for $U = 0$, to the interacting case.

From the continuum RG analysis of the IRLM [2], it is known that there is a length scale l_I associated with this impuirty, analogous to the famous *Kondo cloud* length scale. This emergent length scale depends on the impurity hopping t as $l_I \sim t^{-\alpha(U)}$. The function $\alpha(U)$ is a nontrivial scaling exponent, having value $\alpha = 2$ at $U = 0$, and a minimum value $\alpha = 4/3$ at the so-called self-dual point $U = U_c$ [2,3].

We have found that the I-ϕ curve takes the form $I \sim \sin(\phi/2)$ for $t \to 0$, and that deviations from this form at finite t scale with the ratio l_I/L, where L is the ring size. Using this observation, we were able to extract values of the scaling exponent $\alpha(U)$ for the interacting case, using persistent currents from numerical exact diagonalization. The scaling analysis involves I-ϕ data from several different ring sizes.

More generally, we have now sorted out many of the conceptual issues underlying the I-ϕ behaviors at various values of the interaction U and the coupling t.

Future collaboration with host institution + Projected publications/articles resulting from grant

The current project has now moved to the stage of final calculations and consolidation of results. We hope to prepare a manuscript on the topic in the time scale between half a year to one year.

Collaboration with Dr. Boulat (and hence the host institution) is thus very likely to continue.

I expect this research to lead to at least one publication.

Other comments

I thank the ESF and the INTELBIOMAT program for funding this research visit.

References

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